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Science Education Trajectories: Charting the Course for Teachers, Educators, Researchers, and Policymakers

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ABSTRACT
Science teacher professional development is complex. Phases in a teacher's career necessitate different professional learning opportunities. Furthermore, knowledge bases, practices, and attributes need to be cultivated during these times. For science teachers, it is not always evident how to link professional learning opportunities progressively toward different outcomes, including being a department head, teacher leader, curriculum developer, or even master teacher. In order to spur a discussion about purposeful teacher learning, we use a theory of transformative learning to examine research pertaining to the professional learning of science teachers. The result is a conceptual framework that suggests that teachers should build their knowledge, practices, and attributes in a way that allows them to realize their potential within specific communities. This framework acknowledges that teachers change over time; that knowledge, practices, and attributes are involved in these changes; and that the situated positions of teachers contribute to these changes. Examples associated with this framework are shared in the article to enable educational researchers to approach the study of science teacher development in different ways, which can help guide professional development programming, teacher learning, and potential policy decisions. Most important, this framework offers science teachers a way to consider their own professional growth.

KEYWORDS
science teacher development; science teacher leadership; science teacher learning; teacher continuum

Science teachers are continuously improving their instruction in order to enhance the learning of their students. As teachers improve their instruction, they develop new knowledge, they add to their repertoire of instructional practices, and they cultivate various attributes that support new forms of instruction. The conduits for this learning include various professional development opportunities, which can be composed of workshops, webinars, professional literature, institutes, or courses. These learning opportunities can also occur in venues that include working with student teachers or visiting a museum or natural setting. Both formal and informal professional development opportunities have been described by many, including Loucks-Horsley, Stiles, Mundry, Love, and Hewson (2010) and the Organisation for Economic Co-operation and Development (2009).

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Most professional development experiences for science teachers are focused on improving the instructional practices of teachers (Luft & Hewson, 2014). These professional development experiences often consist of workshops that support teachers to learn some form of standards-oriented instruction (e.g., Borman, Gamoran, & Bowdon, 2008; Newman et al., 2012). Notably missing from the constellation of professional development experiences for science teachers are opportunities to grow beyond the instructional sphere. Although improving the practice and knowledge of a teacher is important in order to improve student learning, teachers also need the opportunity to grow professionally into new educational roles, such as master teachers, curriculum specialists, or even academics.

Discussing the different professional roles available to teachers is important for many reasons. One of the most important reasons may be the high rate of teacher turnover; that is, teachers leave the profession, often in their early years and before they have fully developed professionally. In Australia and the United Kingdom researchers acknowledge the shortage of mathematics and science teachers, but the exact number of teachers who leave the teaching profession in their early years is difficult to determine (Plunkett & Dyson, 2011; The Royal Society, 2007). In the United States, the data are more conclusive, with the National Science Board (2014) reporting that 25% of secondary mathematics and science teachers depart by their third year of teaching. Among all studies of turnover, mathematics and science teacher turnover is most pronounced in challenging schools, which are often ethnically or racially diverse and have a significant number of students living in poverty (Henry, Fortner, & Bastian, 2012; Lankford, Loeb, & Wyckoff, 2002).

Researchers have different ideas about how to combat turnover that often involve different orientations toward professional learning. Some researchers suggest that specifically designed programs can help newly hired teachers negotiate the challenging first years of teaching (e.g., Luft et al., 2011; Smith & Ingersoll, 2004). By participating in induction programs, new teachers receive specific forms of support that help them persist in the classroom beyond a few years. Others suggest that participating in collaborative learning groups is important in cultivating teacher persistence (Borman & Dowling, 2008). As teachers work in a learning community they build important skills, abilities, and connections that assist them in navigating novel experiences. Other researchers suggest that enhancing teachers' professional identity may be critical in terms of their persisting as educators (Lindqvist & Nordänger, 2016). When new teachers build their professional identity, they know what is possible professionally and thus persist in the field of teaching. Across these different orientations toward professional learning is a clear message that providing teachers with purposeful learning opportunities can contribute to their persistence in the profession.

This article is in response to both the narrow forms of available professional development programming for science teachers and the turnover of early career science teachers. It suggests that a more comprehensive view of the teaching profession can provide teachers with a focus on learning that is oriented toward professional growth through professional development. In focusing on this type of learning, teachers can engage in a process of professional transformation that takes into account their current experiences and context in an intentional way. When teachers reconstruct their own views about their current position, they reformulate their roles. This transformative approach toward professional learning may expand professional development opportunities for science teachers and potentially reduce new teacher turnover by elucidating learning opportunities.

We intend for this article to initiate a dialogue about how science teachers can grow into new roles over time, including those beyond the classroom. We offer one way to potentially characterize these roles, which we call *trajectories*. In this article, trajectories are ways in which science teachers can strengthen their knowledge, practices, and attributes and develop intentionally. Trajectories originate with newly hired science teachers and expand to the different roles that teachers can hold in different educational settings.

For science teachers, trajectories provide a view of professional learning that is transformative and purposeful as opposed to episodic and ad hoc. For science teacher educators, trajectories move the discourse of professional learning toward transformative professional learning, which enables teachers to become master teachers, teacher leaders, curriculum developers, or mentors. For educational researchers, trajectories provide a context in which to study science teacher learning. For policymakers, this framework reinforces the importance of supporting science teachers to become accomplished professionals and active contributors to their field of science education.

Transformative learning theory (TLT)

TLT is essential when considering trajectories. TLT was proposed by Mezirow in the 1970s as he explored how women returned to college (see Mezirow, 1978). Over the years, the theory has been expanded and revised to account for better understandings of learning and in response to critiques of TLT (Baumgartner, 2012). The broad nature of TLT has utility in many different fields or contexts that pertain to adult learning (Taylor & Cranton, 2012). For instance, this theory has been used to understand how nursing students learn about aging patients (Mastel-Smith, Nash, & Caruso, 2016), how people reframe their ideas about race (Gambrell, 2016), and how graduate students learn about leadership (Burns, 2016).

The wide appeal of TLT is a result of its broad, yet personal, view of learning. It recognizes that individuals hold a frame of reference that is transformed in response to different situations (Mezirow, 1997, 2012). For example, reframing can occur as a person engages in a new role, plans for a course of action, assesses a situation, or recognizes the need for change (Mezirow, 2012). The ongoing reframing of one's reference point is a result of reflection and discourse, which happens in a specific context and in concert with other individuals. As an individual engages in reflection and discourse, habits of mind and points of view support the reframing process. Habits of mind are ways of thinking, feeling, or acting (to name a few). Points of view are emerging positions about some group, individual, or entity. An important outcome of the reframing process is that individuals become more empowered and autonomous.

An example of this theory in science education can be found in Berry (2016), who sought to understand her own professional growth as a science teacher educator. In using TLT, Berry (2016) was able to examine how she reflected on her own beliefs, values, and practice pertaining to the education of preservice science teachers. Over time, she reconceptualized her role as a science teacher educator. More important, she progressed in understanding that teaching teachers was not about the accumulation of experiences but about making sense of these experiences in order to develop an explicit knowledge of practice and to inform future practice. Ultimately, TLT gave her a heightened awareness about her ongoing transformation to a master science teacher educator.

In this article, we use TLT to consider how science teachers can change in purposeful ways, toward more empowered or autonomous roles. As suggested by Mezirow (1997), we consider the cognitive, conative, and emotional components associated with specific roles. These components, in the presence of different contexts, allow teachers to reflect and engage in a discourse that allows a reframing to a new reference point. We are by no means suggesting that teachers move from one reference point to another in a linear fashion. Instead, by using TLT as a theoretical anchor, we hope to highlight different reference points that can help teachers better recognize and make sense of opportunities, alternatives, and pathways that result in more purposeful professional growth.

Qualities to consider: Knowledge, practices, and attributes

When considering the different and new roles that science teachers can hold, it is important to consider the different qualities that reside within these roles. We have decided to articulate the components of a trajectory by focusing on the professional knowledge, practices, and attributes that are valued in the science education community. They correspond to the cognitive, conative, and emotional components that Mezirow (1997, 2012) envisioned in his TLT.

The component of professional knowledge comprises content knowledge (CK) and pedagogical content knowledge (PCK; Abell, 2007; Berry, Friedrichsen, & Loughran, 2015; van Driel, Berry, & Meirink, 2014). CK and PCK are central to most teacher learning endeavors. The CK and PCK a science teacher needs is often discussed generally in national and international documents. For instance, the *Teachers' Standards* from England (Department for Education, 2012), the *Australian Professional Standards for Teachers* (Australian Institute for Teaching and School Leadership [AITSL], 2013), and the *Teacher Performance Appraisal Technical Requirements Manual* (Ontario Ministry of Education, 2010) state simply that teachers need knowledge of their subject and need to know how to teach this knowledge. There is no elaboration on the quality of the CK or the configuration of PCK within a discipline.

In developing trajectories, the CK and PCK of a teacher should have utility and be oriented toward a current or potential role. For instance, a science teacher certainly needs CK. A simplistic form of CK would be Schwab's (1964) orientation that consists of a syntactical and substantive structure. Syntactical structure reveals the manner in which knowledge is produced in the discipline, which includes the logic and reasoning used by scientists. Substantive structure pertains to the represented knowledge in the discipline and defines the studied areas. This form of CK, however, may need to be tailored for a district science coordinator or a department head.

The component of practices comprises what is enacted in each role. Practices can be general or they can be discipline specific. Practices are often described generally in teacher education policy documents. For instance, AITSL (2013) recommends that teachers be able to plan, structure, and sequence learning programs. In the United States, teachers should understand and be able to use a variety of instructional strategies to encourage student learning (Council of Chief State School Officers, 2011). Discipline-specific practices related to science can involve teaching science or giving feedback about how to teach science. In the United States, the practices of science may consist of creating an explanation using evidence, designing an experiment, or using a model in science, which are found in the Next Generation Science Standards (NGSS Lead States, 2013).

Within different roles, practices can vary. Science teachers, for instance, need to enact learning environments that represent science. Their practices may involve using the scientific practices shared above (NGSS Lead States, 2013) or inquiry-oriented approaches that involve having students ask questions, generate data, or analyze data (National Research Council, 1996). Department heads, in contrast, should know how to support the instruction of their colleagues. Clinical supervision is one approach (e.g., Gall & Acheson, 2011) that a department head can use to provide feedback to a colleague in a way that connects actions to student learning.

Finally, attributes are important in trajectories, and they include areas such as dispositions, beliefs, or attitudes (e.g., Evans, Luft, Czerniak, & Pea, 2014; Palmer, 2011). Attributes are personal constructions that ultimately influence how a science teacher enacts a practice or represents knowledge. For instance, the beliefs of a science teacher can influence the decisions made in a classroom, how a practice is learned, or the selection of a professional learning opportunity (Jones & Leagon, 2014). In science, the beliefs of a teacher often emerge from personal experiences and are shaped through interactions with peers and experiences in the classroom (Jones & Leagon, 2014; Kind, 2016). Although attitudes and dispositions are different, they are similar in their origin and impact on practice and knowledge.

Within a trajectory, attributes should be aligned with the field of science education. For instance, science teachers should hold beliefs and attitudes that support science instruction (Jones & Leagon, 2014). Unfortunately, some science teachers hold attitudes that result in limited science instruction. Elementary teachers are frequently noted as having attitudes that do not support science instruction (Palmer, 2011). Department heads will have a different set of attributes, which are associated with leading a group of people. These attributes should include attitudes that value collective work or beliefs that are oriented toward sound science instruction (Peacock, 2014). Attributes (like practices) vary widely among the different roles, and it is important to recognize their specificity within a role.

Purposeful professional learning: Trajectories

Systems that provide learning opportunities for teachers vary in focus and structure internationally (Hendriks, Luyten, Scheerens, Sleegers, & Steen, 2010; Wei, Darling-Hammond, Andree, Richardson, & Orphanos, 2009). In the presence of these different learning programs, there is a need to contemplate how teachers can grow professionally in terms of their knowledge, practices, and attributes. Developing such a system can benefit all teachers, yet we are most interested in how science teachers can develop professionally.

Unfortunately, discussion about creating scaffolded and coherent professional learning opportunities has been absent in the science education professional development literature (e.g., Luft & Hewson, 2014; National Academies of Sciences, Engineering, and Medicine, 2015). Some studies, however, offer insights. Recent research on teachers' professional vision (Rushton & Criswell, 2015), teacher identity (Avraamidou, 2015), and teacher leadership (Whitworth & Chiu, 2015) offers insights into ongoing professional learning. These areas of research suggest that teachers should be well supported and oriented toward a personal and professional role and that science teachers may benefit from purposefully contemplating their current role. When this occurs, teachers contribute to the educational community in valuable ways, such as through enhancing student learning, guiding school policies, and/or participating in national discussions about science education.

This article addresses the need to articulate the purposeful professional development of science teachers using the concept of trajectories, which are presented through research from the field of science education. Ultimately, these trajectories can guide the professional learning of teachers in purposeful and progressive ways. Trajectories are not learning progressions (see Duschl, Maeng, & Sezen, 2011), as the increasing complexity of knowledge, skills, or attributes is absent, nor are they science teacher learning progressions (see Friedrichsen & Berry, 2015), as they are framed within roles. Instead, trajectories are conceptual roadmaps for teachers that suggest knowledge, practices, and attributes that are connected to professional goals, aspirational positions, or advanced roles. They are pragmatic and grounded in empirical research, and they offer alternative routes toward different roles. They make implicit professional growth explicit, and they emphasize transformation over accumulation.

Articulating science education trajectories (SETs)

Science teachers are professional learners who can become master teachers, science coordinators, department heads, school leaders, educational assessment specialists, and/or curriculum developers. These different roles can comprise professional trajectories that we call *science education trajectories* (SETs). SETs are specific to science education and include reference points that depict the transition of a teacher toward different roles. The reference points in this article are three broad stages of a teacher's career.

In describing SETs, we suggest one way to identify the knowledge, practices, and attributes within different reference points. Our goal is not to represent SETs as fixed pathways but to illustrate how to articulate reference points for teacher learning that are coherent and based on empirical research. By constructing and sharing SETs, those who guide, study, or work with teachers, and teachers themselves, will be better able to direct or engage teachers in coherent and transformative professional learning programs.

The following sections depict our process of developing SETs. It is a general approach that will likely be modified over time. With the insight of other educators, new processes will be articulated that result in SETs. To further clarify a SET, we provide two example SETs in this section of the article along with an example of how a SET can support a teacher's transformation into a new role.

Situated in science

Within each SET an understanding of science is essential. This understanding of science has implications for how student learning is supported in the classroom, how the knowledge of a teacher is extended, and how science is represented in a variety of settings. For teachers engaged in SETs, the substance and direction of their interactions are dictated by their knowledge of science. For example, a science department chair/head in the United States could engage colleagues in a discussion of instruction that draws on models to reveal central ideas in science, whereas a curriculum developer would contemplate how to represent science explanations in classroom materials. These representations of science align with the Next Generation Science Standards (NGSS Lead States, 2013). The views of science that are ultimately embraced in different countries will certainly have international qualities, yet they will be specific to the country.

Constructing SETs

Over a period of 6 weeks we generated a list of different roles that teachers could hold in educational settings. On the list were roles associated with what are considered normal teaching responsibilities, such as master teacher, mentor teacher, teacher leader, and curriculum developer. There were also roles on the list that were outside of normal teaching responsibilities, such as professional development specialist, teacher trainer, or educational policy advisor. Each of us initially generated a list of different roles, and these lists were combined into a master list. We then met virtually to review the master list, which resulted in the clarification of roles, the deletion of duplicate roles, and the identification of new roles. In reviewing the list of roles, we eventually reached a point at which new roles were not easily identifiable. This final list represented potential roles for teachers from more than one national perspective.

The resulting roles were categorized independently by the first two authors of this article. They each used first-level descriptive coding (Miles, Huberman, & Saldaña, 2014) to categorize the potential roles of teachers. The two authors then met to share their coding. Through a process of discussion and consensus, they agreed on six different groups: experienced teacher, private sector, kindergarten–Grade 12 (K–12) school system, informal education, higher education, and policy. The first and second authors believed the experienced teacher group could be a potential reference point. These six groups were shared with the other three authors for their review and comment. After these authors commented, some of the roles were moved to different groups, but the six groups were retained.

The notion of transformation (Mezirow, 1997, 2012) was the guiding framework to suggest how teachers could engage in different roles. A newly hired teacher role designated an entry-level reference point, and the other roles radiated from this point. In considering the different roles, it is important to acknowledge that movement between the roles is not linear. The transformative learning orientation suggests that teachers move from one role to another and that roles are bound by context (e.g., working conditions or opportunities for professional learning). Furthermore, closely aligned roles have less disparity during the reframing process. Figure 1 is one potential representation of the different roles that science teachers can hold. In general, science teachers begin as newly hired science teachers and reframe toward different roles in different working contexts.

This general framework provided the starting point to articulate the different components within different roles and framed by different reference points (e.g., early career teacher and experienced teacher). By articulating different knowledge, practices, and attributes associated with the different roles, teachers could have guidance from one role to another. Such an orientation would result in a continuum of opportunity that could strengthen the work of teachers. Envisioning this continuum with a transformative orientation (Mezirow, 1997, 2012) in the area of science results in SETs.

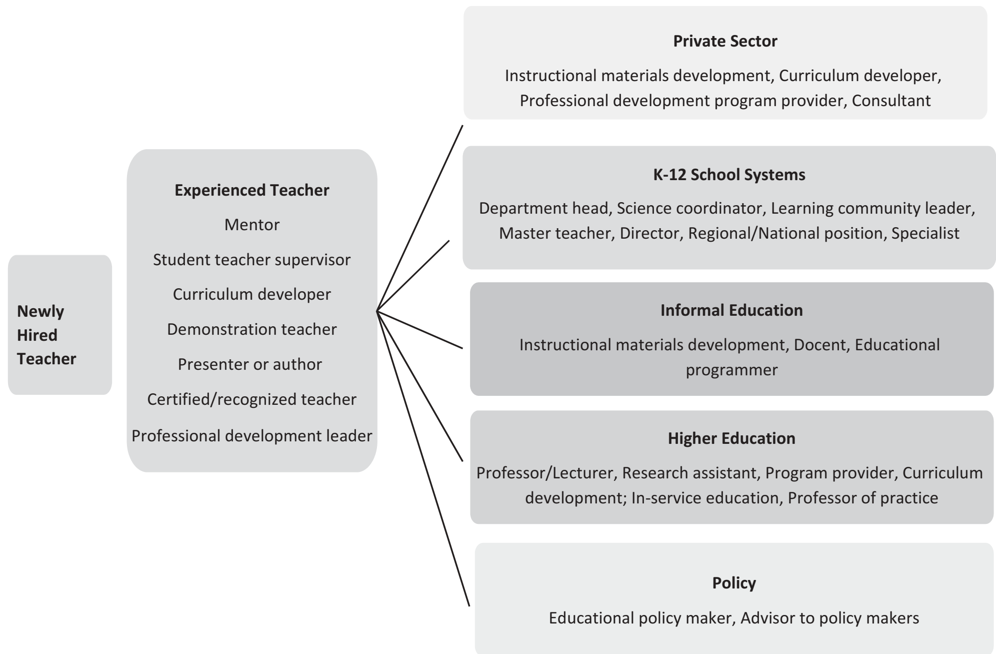

Figure 1. Roles within different reference points. K-12 = Kindergarten–Grade 12.

To begin the articulation of potential SETs, we created generalized definitions for each proposed role in Figure 1. For example, roles in the private nonteaching sector often involve leaving the classroom and entail the development of specific skills to support the dissemination of an educational product. In the United States K–12 system, teachers may reside in schools and provide leadership to colleagues and the school, or they may move to positions that oversee many teachers in a district, region, or area. Informal settings involve positions that occur outside of normal K–12 venues. Higher education positions may connect to K–12 schools and involve the generation and dissemination of new knowledge. Policy positions guide decisions made at a district, regional, state, or national level. Regardless of the setting teachers occupy, their roles include guiding science classroom instruction and science teacher learning. We held similar discussions about teacher roles in the United Kingdom and Australia in order to ensure some common meaning.

When the roles were clarified, two specific trajectories were identified for potential development: department heads/chairs and science coordinators. A review of the research was then conducted in order to identify potential components within these two different roles. Peer-reviewed research studies were gathered through Google Scholar and EBSCO host that addressed department heads/chairs and science coordinators in science education. Research that was of interest was published between 1980 and 2015. Articles with limited details on methodology, data collection, or data analysis and/or with claims that were unsupported or overgeneralized were removed from the review (see Luft, Dubois, Nixon, & Campbell, 2015, for this rubric).

For the science department heads/chairs trajectory, we identified articles using the search terms *department head*, *department chair*, and *department leader*. Ancestry and progeny articles that aligned with the definition of department heads/chairs were also located and reviewed. Eleven articles were identified as appropriate and used in the analysis that produced this trajectory. For the science coordinator trajectory, we completed a similar search using terms including *district leadership* and *district science coordinator*. Ancestry and progeny articles that aligned with the definition of a science coordinator were also located. Thirty-two empirical articles were identified as appropriate in their methodological approach and focus and were used in the development of this trajectory.

A content analysis matrix (Miles et al., 2014) was used to analyze the published research associated with the selected roles and associated reference points. A content analysis matrix is a display about a variable or dimension of interest. In this case, the matrix was bound by a role but recognized the components of knowledge, practices, and attributes within different groupings. In this matrix, newly hired science teachers represented the starting point.

The first and the second authors analyzed the identified papers in either the department head/chair or science coordinator areas. In analyzing the different studies, they used an a priori code of knowledge, practices, or attributes to indicate the supporting examples in each study. Analyzed data were often represented by these a priori codes. The coded areas in each study were then placed in the role in the content matrix. At times several examples were similar, but others were isolated. This preponderance or lack of representation was noted in the matrix.

Each matrix and the associated text were reviewed by the first and second authors to represent the potential transformation of roles over time. In conducting this review, we drew on a growth gradient process (Miles et al., 2014). A growth gradient process is concerned with how variables change over time. In the case of trajectories, we were interested in considering the transformation of knowledge, practices, and attributes within a specific role. In reviewing the different examples associated with the different roles, we considered the quality, the frequency, and the connection of the different examples. Ultimately, brief phrases (Miles et al., 2014) were used to represent important knowledge, practice, or attribute points in the transformative process of becoming a department head/chair or science coordinator. The following sections provide an overview of two potential SETs.

Department heads/chairs

Although some studies explore professional positions of science teachers, only a few (including Melville, Hardy, & Bartley, 2011; Peacock, 2014; Turner, 2003) are associated with science department heads. Department heads/chairs are vital within schools, as these senior colleagues must direct, promote, and support teaching and learning across the department and be responsive to individuals' needs (Melville et al., 2011; Turner, 2003). Studies of department heads/chairs report on the experiences of department heads with colleagues, their personal experiences in the role, and their engagement in a professional development process that leads to being a department head (Khourey-Bowers, Dinko, & Hart, 2005; Lehman, 1994; Melville et al., 2011; Peacock, 2014). Collectively, these studies point to a potential trajectory that includes the knowledge, practices, and attributes associated with becoming and being a department head/chair.

As few studies exist in this area, identifying the knowledge, practices, and attributes of department heads/chairs was not a straightforward process. However, knowledge includes leadership knowledge, science knowledge, and knowledge of science reforms; practices include the ability to negotiate and advocate for science instruction; and attributes include being a representative of a science department and supporting colleagues' development. Again, science underpins all aspects, as an essential component of the daily activity of a department head/chair involves the promotion and enactment of sound science instruction.

Table 1 shows a potential SET for department heads/chairs in science. The trajectory illustrates a transformation of knowledge bases, practices, and attributes, which over time are retained and enhanced within the position.

Science coordinator

This trajectory began with a focus on teacher leaders. The professional learning of teacher leaders is important to consider, as being a leader does not just happen (York-Barr & Duke, 2004). Teacher leaders have many roles that ultimately promote systemic change by supporting emerging and current educational reforms. Studies of teacher leaders in science consider views of teacher leaders' roles, science teacher leaders' identity, and the evaluation of teacher leader programs (Hanuscin, Rebello, & Sinha, 2012; Mentzer, Czerniak, & Struble, 2014). Although studies highlight the importance of teacher leaders, most do not differentiate between leadership roles teachers can pursue, such as department head, curriculum developer, and science coordinator, and the unique knowledge,

Table 1. Needed knowledge, practices, and attributes of a department head/chair.

	Knowledge	Practices	Attributes	Example of a department head/chair
Early career teacher	Subject matter knowledge Curricular knowledge Knowledge of learners Knowledge of context	Assessment and feedback pertaining to students Science instruction Communication to students and others	Build beliefs Emerging identity	Individuals in this role have grown into department heads/chairs by building their abilities to communicate with others, solve problems, and supervise colleagues. In addition, they understand representing and advocating for those in the department.
Experienced teacher	Deepen all knowledge bases	Build assessment, instruction, and communication skills as it pertains to colleagues	Build professional identity	An important quality of a department head/chair is a deep knowledge base in leadership and the reforms in science. These areas are
Department head	Expand knowledge of local and national reforms	Problem-solving skills Negotiation approaches Supervision abilities	Supportive of colleagues Representative of the department	important, as department heads/chairs are often responsible for cultivating a working environment that is supportive and advocating for sound science instruction. Encouraging appropriate instructional approaches and determining how to acquire needed resources are examples of the daily work of department heads/chairs.

Table 2. Needed knowledge, practices, and attributes of a science coordinator.

Reference point	Knowledge	Practices	Attributes	Example of a science coordinator
Early career teacher	Subject matter knowledge Curricular knowledge Knowledge of learners Knowledge of context	Assessment and feedback Science instruction Communication	Build beliefs Emerging identity	Individuals in this role have grown into leaders by deepening their knowledge of curriculum, subject matter, pedagogy, local and national reforms, science education research, professional development, and the administration and management of people and a science program. This depth of knowledge has helped to establish a professional identity that can lead teachers. Coaching, mentoring, supervising teachers, and giving supportive feedback are involved in being a science coordinator. In working with teachers, relationships are important, as is building well-constructed materials or programs. Knowledge, analysis skills, and a well-informed vision are important in this role. While supporting and leading teachers, managing the day-to-day operations of a science program and communicating frequently with all involved individuals is important. Work in a larger science education community occurs through participating and at times leading in professional organizations.
Experienced teacher	Deepen knowledge bases	Build assessment, instruction, and communication skills as it pertains to colleagues	Build professional identity as an adult learning leader	
Science coordinator	Knowledge of teacher development Knowledge of mentoring and supervision Knowledge of local and national reforms Knowledge of administration and management	Be able to make tacit aspects of practice explicit (explicit pedagogical content knowledge) Develop leadership skills and practices Engage with professional organizations Coaching and/or mentoring Administrative duties Communication with multiple stakeholders	Attain local, regional, or national identity as an adult learning leader Develop a strong network and support system for work	

practices, and attributes needed for each (Luft & Hewson, 2014; Whitworth & Chiu, 2015). Although many leadership programs conform to good standards of professional development, creating teacher leaders differs from cultivating effective classroom teachers.

In this trajectory, a science coordinator was parsed out from the teacher leader literature. In science education, these people are responsible for providing professional development to teachers and supporting teachers in their teaching roles. Often these individuals serve in an administrative role and develop strategic plans for science education within their contexts. In the United States, for example, an individual in this type of role may hold the title of a district science coordinator, science supervisor, or science curriculum specialist (Whitworth, 2014).

Table 2 shows the results of an initial review of articles focusing on individuals in this type of position and the knowledge, practices, and attributes needed for this position.

An example: TLT and SETs

Claire earned her secondary science certificate after completing her bachelor of science degree in chemistry. She was hired at a school that was much different from the school she had gone to as a secondary science student and the school where she completed her student teaching. Claire was assigned to teach sections of both chemistry and physics. Even with the mismatch between her prior experiences and her preparation to be a teacher, she was excited to begin her first position.

Two months into her first year of teaching, she met with her mentor, Beatrice. In this session, like many others, her mentor provided suggestions pertaining to her instruction and her monitoring of student learning. Beatrice also encouraged her to contemplate how she was adjusting and adapting as a teacher. Claire quickly shared that she developed all of her physics lesson plans on her own. As a result, she always felt behind in preparing her courses. Beatrice asked Claire to reflect on her approach to preparing for her physics classes and what she might do to build her knowledge and instruction in this area. After some thought, Claire shared that she wanted to be better at planning for the class and that she needed to have more confidence in her CK. To do this, she felt she needed to find a short professional development program that emphasized teaching physics. The prompting by Beatrice forced Claire to reframe her position toward a more empowered position, and as a result she changed her point of view about teaching physics.

Claire looked for different professional development opportunities, but she was worried about the time they required. Adopting a more empowered position, she eventually realized that having this knowledge would help her advance her practice and that her students would benefit. She found a short program that required only a few days of her time over several months.

By the end of the school year, Claire was feeling more comfortable with her instruction in physics. In fact, she was able to envision how additional professional development programming could help her develop into a master teacher. Claire realized that CK was important, but she also began to realize that she needed to build her ability to assess and communicate with students about their progress. In addressing these areas, she would begin to advance her instruction in ways that would improve the learning of her students.

Two years later, Claire was working toward building her capacity as an experienced teacher in the department. She hoped to host a practice/student teacher in the next few years and wanted to make sure she had the knowledge, skills, and attributes to be successful in this role. In considering this potential role, Claire and Beatrice talked frequently about her professional advancement and a SET that pertained to being a master teacher. Claire was able to articulate the areas in which she needed to improve, and she was able to articulate a pathway toward this new role. Beatrice certainly helped Claire understand and become empowered in reaching her new role, which she accomplished by providing opportunities for Claire to reflect on her position and determine how she was going to advance professionally.

The potential of SETs

This article began with a concern about the professional development opportunities that are provided to science teachers. Specifically, science teachers often experience professional development programs that support their classroom instruction in different ways. Although these professional development experiences are important, there is a need to provide science teachers with learning opportunities that support their transformation as teachers. Articulating how science teacher learning can occur purposefully and transformatively is essential (Luft & Hewson, 2014; National Academies of Sciences, Engineering, and Medicine, 2015). Ultimately, these experiences may support the personal professional growth of a teacher as well as retain teachers who may leave the profession.

Teachers can grow professionally in many different ways, yet the first years of teaching are often the most difficult (Luft et al., 2011; Smith & Ingersoll, 2004). During these early years, new teachers need to strengthen and sustain their knowledge, practices, and attributes (Feiman-Nemser, 2001). Professional development programs and colleagues are certainly essential during this period of time. Both can provide personal and professional opportunities to reframe a teacher's point of reference. When this happens, the teacher takes on a more empowered and autonomous role (Mezirow, 1997, 2012).

We have suggested that SETs may be one way to help teachers (especially newly hired teachers) develop in purposeful ways. SETs are professional trajectories framed in TLT and informed by empirical work. They are professional learning opportunities and help guide decisions pertaining to professional learning. In addition, these trajectories align with teacher qualities that are discussed in various teacher education standards documents (e.g., AITSL, 2013; Ontario Ministry of Education, 2010).

SETs are important to those in education for several reasons. For science teachers, SETs allow the envisioning of professional options. Teachers can develop professionally to be effective with their students, or they can consider how they will guide their department as a department head/chair. By having professional options, teachers can contemplate how to configure their professional development experiences. These experiences can result in transformative learning opportunities that are purposeful, as described by Mezirow (2012).

For those who work with teachers, SETs are ways to help teachers envision coherent professional learning experiences. Professional development for teachers should be purposeful and not just a collection of experiences (National Academies of Sciences, Engineering, and Medicine, 2015). SETs are one way for teacher educators to contemplate the coherency of the professional learning opportunities they provide. For example, instead of providing programs that are focused on science instruction, teacher educators could offer a series of programs focused on how to be science leaders. This is an area of need, and more could be done to cultivate teacher leaders (Whitworth & Chiu, 2015). If provided with different coherent professional options, science teachers will ultimately impact student learning in and outside of the classroom.

For those who study teachers, SETs need to be based on empirical work. Studies of knowledge, practices, and attributes are essential in the creation of SETs. Longitudinal studies, studies on CK, and studies of teacher transformation are a few of the more pressing areas in need of examination (Luft & Hewson, 2014; Mezirow, 2012; van Driel et al., 2014). As these studies are completed and SETs are envisioned, SETs can then be connected. SETs are not linear. They are initial descriptions of how a teacher can transform into different positions. They have reference points that are similar, which allows for purposeful movement between positions. Contemplating these connections will be important.

For policymakers, SETs could fill the void regarding standards. Current teacher standards recommend the attainment of knowledge, practices, and attributes (e.g., AITSL, 2013; Department for Education, 2012; Ontario Ministry of Education, 2010). SETs suggest how these different areas may link together within different roles. They also provide policymakers with an expanded view of science teacher learning. That is, science teaching can be a rewarding career in terms of working with students, and it can be a potential gateway to other important educational opportunities.

Finally, for science teachers, science teacher educators, and policymakers, SETs expand the discussion of professional learning beyond typical professional development experiences. They make components of the different professional roles more explicit—an aspect that has been largely absent from the teaching profession and yet is sorely needed in an environment of improving student outcomes and high teacher attrition. SETs also suggest that science teacher learning is not merely an outcome but a process that takes time, requires support, and should be purposeful.

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